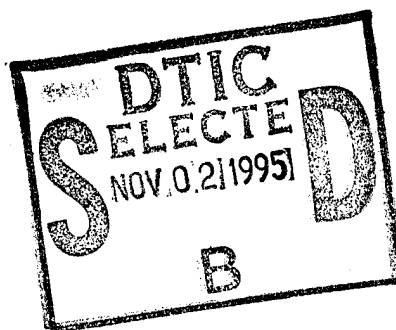




The Effect of Qualitative Explanations and Pictures on Learning, Retention, and Transfer of Procedural Tasks

Betty V. Whitehill
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Procedural Tasks**

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13. ABSTRACT (Maximum 200 words) Two experiments investigated the effects of qualitative explanations and pictures on learning, retention, and transfer of a procedural assembly task. Results showed (1) functional explanations are more effective than structural explanations in learning and remembering a procedural task, however, their effects are diminished when learning subsequent similar tasks, (2) providing pictures facilitates learning but does not help performance once the task has been learned to criterion, and (3) previous experience in a task domain results in positive transfer to new tasks in the same domain.					
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Foreword

This technical report documents two experiments that were conducted in support of the Personnel and Training Technology (PS2A) Block of the 6.2 Mission Support Technology Program Element 0602233N, which was sponsored by the Chief of Naval Research (ONR-342). The goal of both experiments was to determine the effects of explanations and pictures on the learning, retention, and transfer of procedural tasks. The first experiment focused on learning and retention while the second experiment investigated transfer.

The recommendations provided in this report are intended for use by the Chief of Naval Education and Training and subordinate commands.

Appreciation is expressed to the Commanding Officer, Service School Command, San Diego for the outstanding cooperation of the personnel at the Interior Communication Class "A" School and the Radioman Class "A" School.

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Summary

Background and Problem

Procedural tasks represent a significant portion of Navy technical training. Yet, trainees frequently do not retain much of what they have been taught in school about procedural tasks by the time they start working on the job. A related problem is that frequently the equipment used to train procedural skills is similar, but not identical, to the equipment found at the job site. Therefore, in addition to memory loss, job performance may be further degraded if trainees have difficulty transferring skills learned in school to somewhat different equipment on the job. One way to counter the loss of procedural skill is to develop instructional materials that are more resistant to forgetting and more likely to promote transfer of skills to similar tasks and equipment.

Objectives

The objectives of this effort were to investigate the effects of qualitative explanations and pictures on (1) learning and retention of a procedural assembly task, and (2) the ability of subjects to transfer learning from one procedural task to learning a new but similar task.

Method

Experiment I examined the effects of structural and functional explanations in text form and the presence or absence of an assembled device in picture form on learning and retention. The device used in Experiment I was a crane. Subjects ($n = 89$) learned to assemble a loading crane from a model kit and then returned 1 week later to test retention. The effects of structural and functional explanations and pictures were assessed by measuring assembly time, several assembly performance measures, and memory performance on test for names of the device components.

Experiment II replicated Experiment I (except for the retention test) and added a condition involving transfer of learning to a new but similar assembly task. For the transfer task, subjects ($n = 82$) first built a lighthouse from a model kit and then, 1 week later, they assembled the model crane used in Experiment I. In both Experiment I and II, subjects were tested individually and their performance was videotaped to enable scoring at a later time.

Results and Discussion

For Experiment I, providing functional explanations improved performance for both original learning and retention. Use of the picture decreased assembly time during learning but did not affect assembly time during retention. Subjects who did not receive the picture performed better on the memory test for component names.

For Experiment II, learning an assembly task transferred to learning a new but similar task, however, providing explanations produced no differences in performance on transfer. As in Experiment I, use of the picture decreased assembly time during learning but did not affect subsequent assembly performance during transfer. As in Experiment I, subjects who did not receive the picture performed better on the memory test for component names.

Conclusions

Functional explanations can be effective in reducing assembly errors in both learning and retention of a procedural task; however, they do not show significant effects when learning a subsequent similar transfer task and they do not reduce learning time. Providing pictures facilitates initial learning by reducing both errors and learning time but does not improve performance or time once the task has been learned to criterion. Finally, previous experience in a task domain results in positive transfer to new tasks.

Recommendations

The Chief of Naval Education and Training and its subordinate commands should promote the use of functional explanations in training courses and manuals to improve performance and increase retention of procedural tasks. Navy instructional designers and developers should incorporate elaborated explanations of cause and effect relationships in technical training and texts to enhance students' mental models and increase retention in the use of procedural tasks. In addition, pictures should continue to be used in combination with lecture and text during initial learning. Finally, when possible, trainees should be given the opportunity for hands-on learning with more than one type or model of the equipment they will encounter on the job. This will promote transfer of learning when trainees are required to work with systems and devices that are similar, but not identical, to the ones used during training.

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Introduction

Background and Problem

Procedural tasks represent a significant portion of Navy technical training. Wetzel, Van Kekerix, and Wulfeck (1987) analyzed 34,373 training objectives from 246 Navy technical training courses and found that terminal objectives that required the performance of procedural tasks were overwhelmingly the most frequent type of objective. Procedural tasks are ordered sequences of steps or operations performed on a single object or in a specific environment or situation to accomplish a goal. They involve few decisions and are generally performed the same way each time. Procedural tasks vary in (1) the amount of required planning, (2) the number of steps, (3) the amount of built-in cuing, (4) the number of decision points or branches, (5) whether the order of the steps can vary, and (6) if the goals of the task are internal or external to the task, system, or situation. The range and variety of procedural tasks is suggested by a taxonomy of procedural tasks proposed by Konoske and Ellis (1991): (1) operator tasks, (2) maintenance, repair or assembly tasks, (3) paper-based tasks, and (4) tasks of locating information or objects.

Military trainees frequently do not retain much of what they have been taught about procedural tasks in school by the time they start working on the job (Hagman & Rose, 1983; Schendel, Shields, & Katz, 1978; Vineberg, 1975). Some of the factors that have been shown to contribute to this loss include type and complexity of the job-task, amount and quality of the initial training, length of time without practice, and amount and quality of experience encountered on-the-job (Farr, 1987; Wetzel, Konoske, & Montague, 1983). In addition, the equipment used to train procedural skills is frequently similar but not identical to the equipment found at the job site. Therefore, in addition to memory loss, job performance may be further degraded if trainees have difficulty transferring skills learned in school to somewhat different equipment on the job.

One way to counter procedural skill loss is to develop instructional materials that are more resistant to forgetting and more likely to promote transfer of skills to similar tasks and equipment. In this report, we examine the contribution of two techniques to accomplishment of these goals: (1) use of pictures and/or graphics and (2) providing qualitative explanations about the task and equipment.

Pictures and Procedural Skills

Research on learning from text has shown that adding pictures or graphics aid learning and retention if they supplement the text in some meaningful way (Dwyer, 1972, 1978; Gropper, 1966; Royer & Cable, 1976). Levie and Lentz (1982) in a meta-analysis of illustrated text studies concluded that learning and retention are facilitated by illustrations, if the illustrations are directly related to the text. The research question is whether adding pictures will have similar effects on procedural skills.

Studies that have investigated the effects of illustrations on procedural tasks and skills have focused on initial learning of the task rather than on retention or transfer. Booher (1975) compared the effects of several combinations of print and pictures on learning a console operation task and concluded that pictures increase learning speed but that print information is necessary for accuracy. He suggested that learners rely on the text information for learning about procedural steps, while

they use pictures for locating objects. Stone and Glock (1981) investigated an assembly task and found that providing pictures during learning decreased errors. Bieger (1982) found that pictures coupled with assembly instructions facilitated learning of procedural assembly tasks. He hypothesized that pictures supplied operational, contextual, and spatial information that instructions alone did not clearly provide. The results of all these studies are similar to the effects of illustrations on learning knowledge from text.

However, the effects of illustrations on retention of procedural skills may not parallel the retention effects for textual knowledge. If the procedural task involves operating or assembling an actual device, memories of interacting with the device should be more salient than memories of pictures used during the learning process. That is, pictures are not likely to add to the quality or quantity of memory representations formed while working with the actual device. In an experimental situation, if one group learns to criterion with pictures and a second group learns to the same criterion without pictures, there should not be differences in subsequent performance or retention because both groups will have had hands-on experience with the device. While pictures in this situation could facilitate learning, the hands-on experience by subjects in both groups should minimize any retention differences. An exception to this hypothesis might be use of an illustration that provides structural or functional information that supplements hands-on experience, such as a schematic or an annotated exploded diagram.

Qualitative Explanations and Procedural Skills

A second technique for making procedural tasks more memorable for students is providing them with elaborated explanations, analogies, or metaphors about how and why systems are structured and function. Research on learning procedural skills and learning from text has shown that elaborated explanations may enhance the students' mental models and increase retention (Konoske & Ellis, 1991; Mayer, 1989; Smith & Goodman, 1982). In a series of studies of learning from scientific text, Mayer (1989) found that providing students with a conceptual model increased both retention and transfer. The conceptual models in his instruction used both text and diagrams to highlight major objects and actions and the causal relations among them. That is, the models focused on how and why systems work. Smith and Goodman (1982) studied the effects of providing elaborated instructions on learning and performing a procedural assembly task and found that instructions containing functional information resulted in fewer errors. However, they did not assess retention or transfer. Swezey, Perez, and Allen (1991), in a study on transfer of electromechanical troubleshooting skill, found that some level of generic structure and functional knowledge is required for cross domain transfer. Conceptual models, elaborated instructions, and functional explanations are what Navy trainers and training developers refer to as "theory." It is important to determine if and when this "theory" type of information is effective in the learning, retention, and transfer of procedural skills since adding "theory" increases instructional development and design costs as well as the length of instruction.

Research Questions and Hypotheses

Two experiments were designed to examine the effects of different types of explanations coupled with the presence or absence of device pictures on the learning, retention, and transfer of a procedural task. The research questions are: (1) Will qualitative explanations facilitate learning and retention by reducing assembly time and assembly errors? (2) Will the presence of pictures

facilitate learning and retention on the same measures? (3) Will qualitative explanations with pictures facilitate learning and retention on the same measures? and (4) Will qualitative explanations and pictures affect student ability to use the skills learned for one task to perform similar, but not identical tasks (i.e., transfer)?

The overall hypotheses for the two experiments are that (1) qualitative explanations will help learners form mental models that reduce learning and retention errors, but not assembly time (Smith & Goodman, 1982), (2) qualitative explanations will facilitate transfer to the learning of a new task in the same domain, and (3) pictures of the device will reduce both assembly time and errors during learning, but will not differentially affect these measures during retention or transfer.

Experiment I

Experiment I examined the effects of qualitative explanations and pictures on learning and retention of an assembly task. Learning and retention were assessed by assembly time and accuracy (assembly errors) measures. The task was to assemble a motorized model crane from a kit. The kit consisted of a large number of component parts that could be used to assemble a variety of different devices.

Two types of qualitative explanations (structural and functional) were developed (Konoske & Ellis, 1991). Each type of explanation was given both with and without a picture of the assembled crane. The structural explanations dealt with the components of the crane assembly and how and why they interconnect. They emphasized spatial relations and described the component structures, component interrelationships, and physical structure of the assembly; that is, they were static.

The functional explanations provided the same information as the structural explanations but, in addition, included information about the cause and effect relationships underlying the assembly task. These explanations emphasized variations of properties with time and were action oriented. They provided dynamic descriptions of how the assembly worked. The explanations included a parts list with small labeled photos of each kit component. The parts list was provided in all the experimental conditions.

In the treatments where the explanations were accompanied by a picture, the picture was an 8-by 10-inch color photograph of the working model of the crane that clearly displayed the structural location of each component.

The general hypotheses are that functional explanations will facilitate assembly performance learning and retention of the assembly task compared to structural explanations and that the picture of the device will facilitate learning but not retention. More specifically, the functional explanation subjects should make fewer errors during learning and retention than the structural explanation subjects because the information provided by the functional explanations highlights the major objects and actions in a system and the causal relations among them. This should help learners form more effective mental models and aid their understanding of the task, which should facilitate performance (Konoske & Ellis, 1991; Mayer, 1989). Based on Smith's and Goodman's (1982) study, however, there should be no effect for explanations on assembly time measures. Further, picture groups rather than no-picture groups should take less time and make fewer errors while

learning how to build the crane because pictures should provide additional contextual, spatial, and functional information (Bieger, 1982). The effects of pictures should be minimized during retention, however, because subjects will have had hands-on experience with the device.

Method

Subjects

The subjects were 80 male and 9 female enlisted personnel attending the Radioman and Interior Communication Schools at Service School Command, Naval Training Center, San Diego, California. Twenty-seven additional subjects began the experiment but were dropped for scheduling reasons or for failing to follow instructions.

All subjects were randomly assigned to one of four groups: (1) structural explanations with no picture ($n = 20$), (2) structural explanations with picture ($n = 24$), (3) functional explanations with no picture ($n = 22$), and (4) functional explanations with picture ($n = 23$).

The structural explanation groups (1 and 2) received the instructions that consisted of linear/structural assembly instructions presented in a sequence of executable steps. The functional explanation groups (3 and 4) received the same information plus functional explanations describing how and why the assembly components function and interact.

The picture groups (2 and 4) received an 8- by 10-inch color photograph of the finished model crane that clearly displayed all components and electrical wiring along with either the structural or functional explanations. The no-picture groups (1 and 3) received either the structural or functional explanations without the picture. Finally, all four experimental groups were given a parts list with small labeled photos of each component.

Procedure and Materials

Assembly Task Overview and Experimental Design. The task consisted of assembling a working model crane from a Capsela construction kit item number 700 that is similar to Lego kits and is manufactured at Sanyei American Corporation. The crane consists of 46 plastic, metal, and rubber parts. The completed crane has a functional motor-driven crane arm pulley, built around a series of capsules, each having a distinct mechanical or electrical function and joined by octagonal couplings.

For analysis purposes, the assembly task was divided into three separate assemblies: (1) initial assembly, (2) criterion assembly, and (3) retention assembly. First, during the initial assembly phase, subjects learned how to assemble the crane with instructions available. Second, during the criterion assembly phase, subjects assembled the crane from memory without referring to the instructions. Third, during the retention assembly phase, subjects returned after a 1-week retention interval and performed under the same conditions as in the criterion assembly phase.

Because the conditions for initial assembly allowed the subjects to use the assembly instructions and the criterion and retention assemblies did not allow subjects the use of the assembly instructions, the initial assembly was analyzed separately from the criterion and retention

assemblies. The only exception was for the total time analysis for the initial and criterion assemblies. The design for the initial assembly analyses was a 2 explanations (functional versus structural) by 2 picture (no-picture versus picture) between groups factorial. For the criterion and retention assemblies analyses a within-subjects trials factor (criterion versus retention) was added to the 2 (explanations) by 2 (picture) between subjects design.

Initial Assembly Procedures. All subjects were tested individually and videotaped. First, subjects completed an experience questionnaire and rated themselves on their electronic knowledge, manual dexterity, and automotive experience.

After the subjects had read the orientation materials explaining the experimental procedures, they received the crane assembly instructions and picture (if appropriate) to read and study. They were required to return the instructional materials before assembling the crane, but could keep the parts list. Although they could ask for the instructional materials as often as they wanted, they were encouraged to assemble as much as possible before asking for the instructional materials. They were told that once assembled, the crane would be disassembled so that they could assemble it again, but from memory. All subjects were told to assemble the model at their own pace. The experimenter then reviewed the orientation materials with the subject to be sure the subject understood them.

Subjects were then given the crane kit components (scattered on their desk), the assembly instructions (i.e., structural or functional explanations), the picture if appropriate, and the parts list with the small labeled component photos. When the subject completed reading and studying the instructional materials, the materials were handed to the experimenter except for the parts list, which the subject retained at all times. The subjects could then begin assembling the crane with the option to stop and study the instructional materials whenever needed. Two conditions had to be met for a successful assembly: (1) the crane arm pulley had to move in both up and down directions when the power-on switch was activated and (2) the red operating indicator light had to flash when the power switch was turned on. After the subjects had assembled the crane, it was tested for a successful assembly.

Criterion Assembly Procedures. Finally, when the assembled crane had met the two working conditions, the subjects turned their backs while the experimenter disassembled the model crane components. Subjects were then told to reassemble the model without using any of their instructional materials or pictures (if in the picture group). The first correct assembly was called the initial assembly and the final assembly without the instructional materials was called the criterion assembly. If the subject was unable to assemble the model crane during the criterion assembly phase and requested the instructional materials back, then that assembly was not counted as the criterion assembly. Instead, they were given a second criterion assembly trial. This second criterion assembly trial was counted as the criterion assembly and both the initial assembly and the first criterion trial were scored as the initial assembly phase.

Upon completion of the criterion assembly, subjects' memory for the component names was tested. Subjects were given a sheet with numbered photos of the 19 components and a paper-and-pencil fill-in-the-blank test and told to fill-in the 19 names by the numbers that corresponded to the numbers on the photo sheet. When they had completed the fill-in-the-blank test, the completed test paper was returned to the experimenter. Subjects kept the numbered photo sheet and were then

given the paper and pencil matching test. They were told to match the list of 19 component names on the left with the corresponding numbers from the component photos. When done, subjects handed the completed matching test to the experimenter. All subjects were given an appointment for the next week to return at the same time for one more assembly. Subjects were briefed not to reveal information about the study.

Retention Assembly Procedures. Subjects returned 1 week later to build the model without the instructional materials or picture (if in the picture groups). This was called retention assembly. All subjects were given the model crane components and the parts list with the labeled photos. Subjects were told to assemble the model at their own pace without using the instructional materials. If, however, they were unable to complete the assembly, they were given the instructional materials under the same conditions as in the initial learning phase. Upon completing the retention assembly, subjects were administered the same fill-in-the-blank and matching tests that they took at the end of the first week. Subjects were debriefed and thanked for their participation in the study.

Dependent Measures

Individual Difference Measures. The subjects used a 4-point system (1 = never and 4 = many times) to rate themselves on how often they had used model kits and worked on their own or other people's cars; along with rating themselves on their familiarity in electrical knowledge, manual dexterity, and mechanical ability using a 5-point system (1 = very poor and 5 = excellent).

Time Measures. Time measures in minutes included the (1) total time for the initial assembly plus criterion assembly, (2) initial assembly time only, (3) criterion assembly time only, (4) retention assembly time (1 week later), and (5) study time during the initial assembly. Additional time measures of subjects in the picture conditions involved the time spent (1) looking at the picture only, (2) reading the instructions only, and (3) looking at the picture and the instructions simultaneously.

Assembly Measures. The assembly measures included (1) number of restarts (where the subjects disassembled a complete section of the model crane and started over), (2) number of times subjects asked for the instructional materials, and (3) total number of errors. The total number of errors was divided into critical (an error that would make a successful assembly impossible) and noncritical errors (the crane works but the components are not assembled as specified).

Component Name Test Measures. Scores on these measures consisted of the number of items correct for the 19 fill-in-the-blank and matching test items administered after the criterion assembly and after the retention assembly.

Results and Discussion

Individual Difference Measures

A 2 (explanations) by 2 (pictures) analysis of variance (ANOVA) performed on the Experience Questionnaire revealed no significant differences for the main effects of explanations, picture, or

the interaction, $F(1,85) = .02$, $p < .87$, $F(1,85) = .46$, $p < .49$, and $F(1,85) = .04$, $p < .83$, respectively. Table 1 presents the means and standard deviations for this analysis.

Table 1
Experiment I:
Means for Experience Scores

Structural N-P <i>n</i> = 20		Structural PIC <i>n</i> = 24		Functional N-P <i>n</i> = 22		Functional PIC <i>n</i> = 23	
<i>Mean</i>	<i>S.D.</i>	<i>Mean</i>	<i>S.D.</i>	<i>Mean</i>	<i>S.D.</i>	<i>Mean</i>	<i>S.D.</i>
15.25	02.69	14.00	03.25	15.00	03.38	14.69	02.80

Note. N-P = No-Picture, PIC = Picture.

(The higher the mean score, the greater the experience.)

Time Measures

Initial Assembly. For the time measure analysis, the subjects' activities during initial assembly were divided into study time and assembly time. Study time was the time subjects had the instructional materials available, while assembly time was the time spent assembling the crane.

A 2 (explanations) by 2 (picture) ANOVA on total time for initial assembly time plus the criterion assembly time showed significant differences between the picture and no picture groups, $F(1,85) = 5.64$, $p < .02$. Subjects that had the picture available spent less time to complete both assemblies than the no-picture subjects. There were no differences for explanations and no significant interaction, $F < 1$ and $F(1,85) = 3.29$, $p < .07$, respectively. Table 2 presents the means and standard deviations for this analysis.

A 2 (explanations) by 2 (picture) ANOVA on the initial assembly time also revealed significant differences for the picture variable, $F(1,85) = 7.46$, $p < .008$. There were no other significant effects. Again, the picture groups took less time than did the no-picture groups for initial assembly. As hypothesized, pictures facilitated learning (Bieger, 1982; Booher, 1975). The functional explanations had no effect on learning which is consistent with previous results (Smith & Goodman, 1982). Table 2 presents the means and standard deviations for this analysis.

A 2 (explanations) by 2 (picture) ANOVA was conducted on number of minutes spent studying the instructional materials during the initial assembly. Subjects in the picture groups spent significantly less time studying than did the subjects in the no-picture groups, $F(1,85) = 13.53$, $p < .000$. The same analysis was also performed on the percent of initial assembly time spent studying. Again, subjects in the picture groups spent proportionately less time studying the instructional materials than did the no-picture groups, $F(1,85) = 10.33$, $p < .002$. In general, having a picture decreased learning time for the initial assembly (Booher, 1975). There were no study time differences for explanations and no interaction. Table 2 presents the means and standard deviations for this analysis.

Table 2

**Experiment I:
Means for Time Measures with Standard Deviations**

	Structural N-P <i>n</i> = 20		Structural PIC <i>n</i> = 24		Functional N-P <i>n</i> = 22		Functional PIC <i>n</i> = 23	
Assembly Time (Min.)	<i>Mean</i>	<i>S.D.</i>	<i>Mean</i>	<i>S.D.</i>	<i>Mean</i>	<i>S.D.</i>	<i>Mean</i>	<i>S.D.</i>
Initial & Criterion Time	84.20	25.47	81.20	27.00	91.09	28.67	67.69	24.39
Retention Time	19.95	13.16	24.06	14.86	19.68	11.32	18.82	09.72
Initial Time	68.00	19.62	64.58	24.86	78.31	25.77	53.73	21.99
Criterion Time	16.20	11.07	16.62	10.82	12.77	06.86	13.95	08.05
Study Time	35.95	13.45	26.33	15.66	40.45	22.23	24.73	11.72
Study Activities (%)			<i>Mean</i>	<i>S.D.</i>			<i>Mean</i>	<i>S.D.</i>
Study time for Picture			33%	25			25%	25
Study time for Instruction			28%	19			25%	19
Study Time for Both			38%	30			49%	29
Study Activities (Min.)			<i>Mean</i>	<i>S.D.</i>			<i>Mean</i>	<i>S.D.</i>
Study time for Picture			07.54	06.07			06.39	07.75
Study time for Instruction			08.45	08.05			06.60	06.21
Study Time for Both			10.29	11.46			11.78	07.44

Note. N-P = No-Picture, PIC = Picture, Both = Both Picture + Instruction.

A 2 (structural/picture vs. functional/picture) by 3 (look at instructions only vs. look at picture only vs. look at both simultaneously) repeated measures analysis was conducted on time allotted for each type of study activity by subjects in the picture groups during initial learning. There were significant differences among the three study activities, $F(2,90) = 3.51$, $p < .03$, but no differences for type of explanation and no interaction. Simple contrasts comparing the three study activities, revealed that subjects spent more time looking at both pictures and instructions simultaneously than looking at either the picture, $F(1,45) = 4.35$, $p < .04$, or the instructions, $F(1,45) = 3.87$, $p < .05$. Contrasts showed no differences in time spent looking at the picture versus the instructions, $F < 1$.

The same 2 x 3 analysis was performed on the percentage of time spent in each study activity. Again, there were significant differences among the three study activities, $F(2,90) = 4.19$, $p < .01$ and no other significant effects. Simple contrasts comparing the main effects for study activity showed a pattern of results similar to the analysis on actual time with subjects spending more time looking at both pictures and instructions simultaneously than looking at the instructions, $F(1,45) = 7.16$, $p < .01$. However, there was only a marginal difference in the amount of time subjects spent looking at both pictures and instructions simultaneously versus looking at the picture only, $F(1,45) = 3.70$, $p < .06$. Contrasts on the percentage of time spent in each study activity showed no differences in the time spent looking at the picture versus the instructions, $F < 1$. Means and standard deviations for actual time and percentage time spent in the three study activities are shown in Table 2. The study activity results are consistent with Bieger's (1982) conclusions that pictures coupled with assembly instructions provide operational, contextual, and spatial information that text alone does not supply.

Criterion and Retention Assemblies. A 2 (explanations) by 2 (picture) by 2 (trials) repeated measures ANOVA was conducted on assembly time. (Remember that the "trials" variable is the criterion vs. retention assembly.) There were no significant differences for the main effects of explanations and pictures, nor was there a significant interaction for the between subjects effects, $F(1,85) = 2.28, p < .13$, $F(1,85) = .38, p < .54$, $F(1,85) = .28, p < .60$, respectively. However, as expected, subjects took a significantly longer time to complete the retention assembly than the criterion assembly, $F(1,85) = 16.46, p < .000$. As predicted, pictures facilitated learning but not performance once the task was learned to criterion. Hands-on experience with the device presumably minimized the absence of the picture for the no-picture subjects once they achieved criterion. Again, functional explanations did not have an effect on time.

Summary Time Measures. Having a picture significantly improved learning speed during the initial assembly but it had no significant effects during criterion and retention assemblies. Further, since the subjects took longer to complete the retention assembly than the criterion assembly, there was forgetting over the 1-week retention interval. As expected, explanations had no effect on time measures during any phase of the experiment (Smith & Goodman, 1982).

Finally, subjects in the faster learning picture groups spent more time looking at the picture and the instructions together. This is consistent with the findings that text with pictorial illustrations is more effective during learning (Bieger, 1982; Guri-Rosenblit, 1988; Stone & Glock, 1981).

Assembly Measures

Initial Assembly. A 2 (explanations) by 2 (picture) ANOVA was performed for each of the assembly measures for the initial assembly. Table 3 presents the means and standard deviations for all the initial assembly measures. There were no significant effects for the number of total errors, critical errors, and number of time subjects asked for the instructions back. The effects of explanations on these measures may have been minimized during the initial assembly because subjects were forming, instead of using, mental models of the task.

Table 3
Experiment I:
Means for Initial Assembly Measures

	Structural N-P <i>n</i> = 20		Structural PIC <i>n</i> = 24		Functional N-P <i>n</i> = 22		Functional PIC <i>n</i> = 23	
	<i>Mean</i>	<i>S.D.</i>	<i>Mean</i>	<i>S.D.</i>	<i>Mean</i>	<i>S.D.</i>	<i>Mean</i>	<i>S.D.</i>
Total errors	07.70	05.93	12.58	18.24	12.22	11.20	09.00	10.82
Critical errors	06.25	05.83	11.20	11.06	09.90	10.29	08.08	10.72
Non-critical errors	01.45	00.99	01.37	01.43	02.31	02.27	00.91	01.08
Restarts	00.50	00.82	00.95	01.65	01.22	02.68	00.08	00.28
Instructions Back	10.70	08.67	07.41	09.65	11.40	14.74	10.73	15.07

Note. N-P = No Picture, PIC = Picture, Instructions Back = Number of requests to see the instructions.

For restarts, there was a significant interaction, $F(1,85) = 5.23, p < .02$, but no significant main effects. A Tukey's post hoc test compared all four groups and found that the number of restarts was

significantly lower for subjects receiving functional explanations and picture than for the other three groups, which did not differ, $p < .05$. While functional explanations did not affect learning speed or the number of critical errors made, they apparently, in conjunction with pictures, helped students formulate models during learning that reduced the number of times sections of the crane needed to be completely disassembled for another assembly restart.

For non-critical errors, there was a significant main effect for picture groups and a significant interaction, $F(1,85) = 5.26$, $p < .02$ and $F(1,85) = 4.13$, $p < .04$, respectively. A Tukey's post hoc comparison showed that fewer non-critical errors were made by subjects given functional explanations and the picture than by the other three groups, which did not differ, $p < .05$. Most of the non-critical errors occurred in assembling the base of the crane. The no-picture subjects were more prone to making errors in assembling the crane base because the crane would still function even if the base was not correctly assembled. No-picture subjects could misread or misinterpret the base assembly instructions and still produce a working crane. If picture-subjects did not read the instructions correctly they could refer to the picture to correct their errors.

Criterion and Retention Assemblies. A 2 (explanations) by 2 (pictures) by 2 (trials), repeated measures ANOVA was conducted on total number of errors, number of restarts, non-critical errors, and critical errors. Table 4 presents the means and standard deviations for these analyses. There were no significant main effects or interactions for non-critical errors. Overall, very few non-critical errors were made during the criterion and retention assemblies. For restarts, there was a significant trials effect, $F(1,85) = 6.59$, $p < .01$, and no other significant effects. As expected, there were more restarts during the retention assembly.

Table 4
Experiment I:
Means for Criterion and Retention Assembly Measures

	Structural N-P <i>n</i> = 20		Structural PIC <i>n</i> = 24		Functional N-P <i>n</i> = 22		Functional PIC <i>n</i> = 23	
	<i>Mean</i>	<i>S.D.</i>	<i>Mean</i>	<i>S.D.</i>	<i>Mean</i>	<i>S.D.</i>	<i>Mean</i>	<i>S.D.</i>
Criterion								
Total errors	06.20	07.60	08.45	18.88	02.95	02.29	03.17	04.25
Critical errors	04.90	07.60	07.50	16.36	02.00	02.18	02.43	03.55
Non-critical errors	01.30	01.08	00.95	02.89	00.95	00.89	00.73	01.25
Restarts	00.15	00.36	00.41	01.13	00.00	00.00	00.17	00.65
Retention								
Total errors	10.00	08.98	13.70	15.58	06.77	07.78	09.17	11.44
Critical errors	09.00	09.17	12.92	13.71	05.27	07.56	07.91	11.07
Non-critical errors	01.00	01.07	01.41	02.93	01.50	01.30	01.26	01.38
Restarts	00.30	00.92	01.04	01.60	00.54	01.26	00.30	00.63
Instructions Back	00.20	00.69	00.66	01.20	00.77	02.20	00.47	01.03

Note. N-P = No-Picture, PIC = Picture.

For total errors, there were significant main effects for explanations and trials, $F(1,85) = 4.81$, $p < .03$ and $F(1,85) = 10.32$, $p < .002$, respectively, and no other significant effects. The same pattern of results was found for critical errors. The main effects for explanations, $F(1,85) = 5.59$, $p < .02$ and trials, $F(1,85) = 11.11$, $p < .001$, were both significant, with no other significant effects. Subjects in the functional explanations groups made fewer total and critical errors than those in the structural explanations groups for both the criterion and retention assemblies. In addition, fewer total and critical errors were made by all subjects during the criterion assembly than during the retention assembly. As predicted, functional explanations resulted in better performance once the subjects learned the task to criterion. This result is consistent with Smith and Goodmans' (1982) findings. Apparently, the addition of functional information produced mental representations of the task that enhanced both criterion and retention performance (Mayer, 1989).

Component Names Tests

A 2 (explanations) by 2 (pictures) by 2 (type of test, fill-in-the-blank vs. matching) by 2 (trials) repeated measures ANOVA was conducted on the written tests that followed completion of the criterion and retention assemblies. There were significant main effects for pictures, type of test, and trials, $F(1,85) = 5.41$, $p < .02$, $F(1,85) = 186.75$, $p < .000$ and $F(1,85) = 10.67$, $p < .002$, respectively. Subjects in the no-picture groups scored higher than subjects in the picture groups. Overall, subjects scores on the matching test were higher than scores on the fill-in-the-blank test, and scores were higher following the retention assembly than following the criterion assembly. There was also a significant type of test by trials interaction, $F(1,85) = 6.24$, $p < .01$. Simple effects tests showed significant differences between trials for the fill-in-the-blank test, $F(1,85) = 10.00$, $p < .002$ but not for the matching test. All subjects performed better after the retention assembly on the fill-in-the-blank test but not on the matching test. This interaction may have resulted from a ceiling effect for performance on the matching test, which was over 93 percent for all groups at each interval. Table 5 presents the means and standard deviations for this analysis.

Table 5

Experiment I: Means for Component Names Test

	Structural N-P <i>n</i> = 20		Structural PIC <i>n</i> = 24		Functional N-P <i>n</i> = 22		Functional PIC <i>n</i> = 23	
	<i>Mean</i>	<i>S.D.</i>	<i>Mean</i>	<i>S.D.</i>	<i>Mean</i>	<i>S.D.</i>	<i>Mean</i>	<i>S.D.</i>
Fill-in (End of week 1)	14.00	04.10	11.29	04.04	12.72	04.68	11.82	03.71
Fill-in (End of week 2)	14.15	03.46	12.50	04.30	14.27	03.12	13.91	02.98
Match (End of week 1)	18.10	01.16	17.25	02.32	17.90	01.30	17.82	01.46
Match (End of week 2)	18.25	00.91	17.67	01.94	18.22	00.92	18.17	01.33

Note. N-P = No Picture, PIC = Picture (Possible Score = 19).

The interesting findings for the component name test measure are that subjects in the no-picture groups performed better than did subjects in the picture groups and that subjects performed better after the retention assembly than after the criterion assembly. Apparently, subjects in the no-picture groups referred to the component parts list more to process the written instructions, which

enhanced memory for the part names. Further, the testing after the criterion assembly may have served as a learning trial, which enhanced performance on the test following the retention assembly. The high scores on the matching test, which followed the fill-in-the-blank, test indicate that subjects may have learned from the first test. Spitzer (1939) and Landauer and Ainslie (1975) found facilitative effects for repeated testing.

Experiment II

The objective of Experiment II was to determine the effects of qualitative explanations and pictures on the ability of subjects to transfer learning from one assembly task to another. Three hypotheses are tested.

First, subjects who learn one assembly task and then learn a second similar task (i.e., transfer subjects) will perform more effectively and efficiently on the second task than will subjects who have learned the second task without having learned the previous one (i.e., control subjects). A number of studies that show transfer across similar tasks (e.g., Allen, Hays, & Buffardi, 1986; Mayer, 1989; Swezey et al., 1991) support this hypothesis.

The second hypothesis is that functional explanations will help transfer subjects form better mental models than structural explanations. This should result in transfer subjects in the functional explanations group making fewer errors than transfer subjects in the structural explanations group while learning the second task. In the analysis, this prediction should produce an interaction between the explanations variable and the transfer-control variable for the number of errors made during assembly of the second task. That is, the predicted decrease in number of errors from the control to the transfer conditions for subjects receiving functional explanations should be greater than for subjects receiving structural explanations.

The third hypothesis is that pictures will decrease study and assembly time for the control and the transfer subjects. Although pictures should reduce study and assembly time for both groups, and experience with the first task should result in faster study and assembly times for the transfer group, no differential effects for the transfer and control groups for pictures are predicted. Hands-on experience with the device during the first task for the no-picture groups should minimize differential effects for the transfer group.

Method

Subjects

The subjects were 155 male (80 from Experiment I) and 16 female (9 from Experiment I) enlisted personnel attending the Radioman and Interior Communications Schools at Service School Command, Naval Training Center, San Diego, California. Fifty-three (27 from Experiment I) additional subjects began the experiment but were dropped for scheduling reasons or for failure to follow instructions.

Treatments, Procedure, and Design

The explanation and picture treatments used in Experiment I were replicated in Experiment II and crossed with a between-subjects-transfer versus no-transfer treatment. The procedures used were identical to the procedures used during the initial assembly for Experiment I.

Subjects in the transfer groups first built a model lighthouse from the Capsela 700 kit under the same conditions used in the initial assembly of Experiment I. That is, they completed an initial and criterion assembly. One week later they returned and assembled the model crane under the same conditions. Subjects in the no-transfer control condition were the subjects in Experiment I. Their initial and criterion assembly from Experiment I provided the control group data. The result was a 2 explanations (functional vs. structural) by 2 pictures (pictures vs. no-pictures) by 2 transfer (transfer vs. control) between subjects design. All analyses using this design were performed on the model crane assembly. As in Experiment I, the initial and criterion assemblies were analyzed separately except for the total time analysis. The lighthouse assembly was also analyzed separately to determine if the pattern of results was similar to the week 1 crane assembly in Experiment I. A similar pattern was expected because the lighthouse and model crane assemblies were rated equal in difficulty by the Capsela instructional materials and by an analysis using the U.S. Army's procedure for predicting task retention based on task difficulty (TRADOC Form 3211-R).

Dependent Variables

All dependent variables defined in Experiment I were analyzed in Experiment II.

Results and Discussion

Lighthouse Analyses

The pattern of results for the lighthouse assembly was similar to the pattern for the initial and criterion crane assemblies in Experiment I. For total time, (i.e., initial and criterion time) a 2 (explanations) by 2 (picture) ANOVA revealed significant differences for the picture variable, $F(1,78) = 12.33, p < .001$. The picture groups took less time than the no-picture groups. There were no significant differences for explanations or an interaction. For the initial assembly, there were no significant differences for the number of restarts, number of critical errors, or the number of times subjects asked for the instructions back. As in Experiment I, subjects in the picture groups made fewer non-critical errors, $F(1,78) = 9.42, p < .003$, than subjects in the no-picture groups. For the criterion assembly, there were no significant effects for any of the dependent measures.

The results for the recall and recognition tests were also similar to Experiment I. No-picture subjects scored higher than picture subjects, $F(1,78) = 10.36, p < .002$, and scores on the matching test were higher than scores on the fill-in tests, $F(1,78) = 166.04, p < .000$.

Individual Difference Measures

A 2 (explanations) by 2 (pictures) by 2 (transfer) between groups analysis of variance (ANOVA) was performed on the Experience Questionnaire for the subjects in Experiment II. No

significant differences were found. Table 6 presents the means and standard deviations for each group.

Table 6
Experiment II:
Means for Experience Scores

Structural N-P <i>n</i> = 20		Structural PIC <i>n</i> = 22		Functional N-P <i>n</i> = 21		Functional PIC <i>n</i> = 19	
<i>Mean</i>	<i>S.D.</i>	<i>Mean</i>	<i>S.D.</i>	<i>Mean</i>	<i>S.D.</i>	<i>Mean</i>	<i>S.D.</i>
13.70	02.65	14.31	03.19	14.14	02.28	15.31	03.14

Note. N-P = No-Picture, PIC = Picture.

(The higher the mean score, the greater the experience.)

Time Measures

A 2 (explanations) by 2 (picture) by 2 (transfer) ANOVA was performed on total learning time (i.e., initial plus criterion time). There were significant main effects for transfer and pictures and no other effects or interactions. The transfer subjects required less time than control subjects to complete the assembly, $F(1,163) = 88.31, p < .000$, and picture subjects completed it faster than no-picture subjects, $F(1,163) = 11.94, p < .001$. Table 7 presents the means and standard deviations for all time measures.

A 2 (explanations) by 2 (picture) by 2 (transfer) between subjects ANOVA on initial assembly time revealed significant main effects for the transfer and picture conditions, $F(1,163) = 86.20, p < .000$ and $F(1,163) = 15.89, p < .000$, respectively. Again, the transfer and picture groups required less time to complete the assembly.

A 2 (explanations) by 2 (picture) by 2 (transfer) ANOVA was conducted on study time during the initial assembly. There were significant main effects for the transfer and the picture conditions, $F(1,163) = 57.57, p < .000$ and $F(1,163) = 31.67, p < .000$, respectively. The transfer groups spent less time studying than the control groups and picture groups required less time than the no-picture groups.

For the picture groups, the subjects study time during initial learning was separated into three study activities: (1) look at the picture, (2) look at instructions, and (3) look at both simultaneously. A 2 (explanations) by 2 (transfer) by 3 (study activities) ANOVA was conducted on percentage of time spent in each study activity. There were significant differences among the three study activities, $F(2,168) = 4.16, p < .017$, but no differences for type of explanation. However, there was a three-way interaction, $F(2,168) = 3.72, p < .026$. A simple effects analysis for each type of individual study activity (i.e., picture, instructions, and both) revealed significant differences among groups for the picture and both simultaneously activities but not for the instructions only activity. The findings were that subjects in the control functional explanations group spent significantly more time looking at both the picture and the instructions simultaneously than subjects in the transfer functional group, $F(1,84) = 6.80, p < .01$, while subjects in the transfer functional group spent significantly more time looking at the picture alone than subjects in the

control functional group, $F(1,84) = 6.94, p > .01$. Evidently, transfer subjects exposure to the functional instructions in building the lighthouse provided them with enough functional knowledge so that they spent significantly less time with instructions while learning the transfer task.

Table 7

**Experiment II:
Means for Time Measures**

Control Group	Structural N-P <i>n</i> = 20		Structural PIC <i>n</i> = 24		Functional N-P <i>n</i> = 22		Functional PIC <i>n</i> = 23	
Assembly Time (Min.)	<i>Mean</i>	<i>S.D.</i>	<i>Mean</i>	<i>S.D.</i>	<i>Mean</i>	<i>S.D.</i>	<i>Mean</i>	<i>S.D.</i>
Initial & Criterion Time	84.20	25.47	81.20	27.00	91.09	28.67	67.69	24.39
Initial Time	68.00	19.62	64.58	28.46	78.31	25.77	53.73	21.99
Criterion Time	16.20	11.07	16.62	10.82	12.77	06.86	13.95	08.05
Study Time	35.95	13.45	26.33	15.66	40.45	22.23	24.73	11.72
Study Activities (%)			<i>Mean</i>	<i>S.D.</i>			<i>Mean</i>	<i>S.D.</i>
Study time for Picture			33%	25			25%	25
Study time for Instruction			28%	19			25%	19
Study Time for Both			38%	30			49%	29
Transfer Groups	Structural N-P <i>n</i> = 20		Structural PIC <i>n</i> = 22		Functional N-P <i>n</i> = 21		Functional PIC <i>n</i> = 19	
Assembly Time (Min.)	<i>Mean</i>	<i>S.D.</i>	<i>Mean</i>	<i>S.D.</i>	<i>Mean</i>	<i>S.D.</i>	<i>Mean</i>	<i>S.D.</i>
Initial & Criterion	53.30	16.61	42.72	11.70	56.71	14.17	49.31	12.23
Initial Time	41.55	13.84	31.27	09.30	45.38	11.79	37.36	10.17
Criterion Time	11.75	05.76	11.45	04.05	11.33	05.53	11.94	05.31
Study Time	22.10	10.73	11.54	05.42	21.14	07.30	13.21	05.02
Study Activities (%)			<i>Mean</i>	<i>S.D.</i>			<i>Mean</i>	<i>S.D.</i>
Study time for Pictures			38%	32			48%	32
Study time for Instruction			24%	25			26%	23
Study time for Both			46%	35			24%	25

Note. N-P = No-Picture, PIC = Picture, Pic = Picture, Inst = Instruction, Both = Picture + Instruction.

A 2 (explanations) by 2 (picture) by 2 (transfer) ANOVA was conducted on criterion assembly time. The only significant effect was that the transfer group took significantly less time than the control group, $F(1,163) = 7.89, p < .006$.

In summary, as predicted the experience gained from learning to assemble the lighthouse transferred to the crane and resulted in faster learning time. Also, as found in experiment 1, pictures improved learning time in all conditions during the learning task of the initial assembly but the effects of pictures did not carry over to the criterion assembly.

Assembly Measures

Initial Assembly. A 2 (explanations) by 2 (picture) by 2 (transfer) between groups ANOVA was performed for each of the assembly measures for the initial assembly. There were no

significant differences for number of times subjects asked for the instructions back. Table 8 presents the means and standard deviations for all of the initial assembly measures.

Table 8
Experiment II:
Means for Initial Assembly Measures

Control Group	Structural N-P <i>n</i> = 20		Structural PIC <i>n</i> = 24		Functional N-P <i>n</i> = 22		Functional PIC <i>n</i> = 23	
	<i>Mean</i>	<i>S.D.</i>	<i>Mean</i>	<i>S.D.</i>	<i>Mean</i>	<i>S.D.</i>	<i>Mean</i>	<i>S.D.</i>
Total errors	07.70	05.93	12.58	18.24	12.22	11.20	09.00	10.82
Critical errors	06.25	05.83	11.20	11.06	09.90	10.29	08.08	10.72
Non-critical errors	01.45	00.99	01.37	01.43	02.31	02.27	00.91	01.08
Restarts	00.50	00.82	00.95	01.65	01.22	02.68	00.08	00.28
Instructions Back	10.70	08.67	07.41	09.65	11.40	14.74	10.73	15.07
Transfer Groups	Structural N-P <i>n</i> = 20		Structural PIC <i>n</i> = 22		Functional N-P <i>n</i> = 21		Functional PIC <i>n</i> = 19	
	<i>Mean</i>	<i>S.D.</i>	<i>Mean</i>	<i>S.D.</i>	<i>Mean</i>	<i>S.D.</i>	<i>Mean</i>	<i>S.D.</i>
Total errors	02.50	01.60	05.95	09.30	05.00	05.13	04.78	06.82
Critical errors	01.75	00.91	05.40	08.94	03.52	04.82	04.00	07.04
Non-critical errors	00.75	01.11	00.54	00.80	01.47	01.28	00.78	01.18
Restarts	00.15	00.48	00.91	00.29	00.28	00.56	00.21	00.41
Instructions Back	07.10	06.12	06.68	06.77	10.14	12.62	08.05	10.17

Note. N-P = No-Picture, PIC = Picture, Instructions Back = Number of requests to see the instructions.

Significantly fewer total errors (critical plus non-critical) were made by the transfer groups than the control groups during the initial assembly, $F(1,163) = 18.81, p < .000$. Although there were no significant main effects for explanations or pictures, there was a two-way interaction, $F(1,163) = 4.93, p < .02$. However, a Tukey's post hoc test found that no two groups were significantly different at the .05 level.

As in total errors, there was a significant difference for critical errors between the transfer and control groups, $F(1,163) = 16.30, p < .000$. As expected, the transfer groups made fewer critical errors. There was no significant interaction.

Very few non-critical errors were made in either the control or transfer groups as shown in Table 8. There were significant main effects for picture and transfer, $F(1,163) = 8.48, p < .004$ and $F(1,163) = 9.19, p < .003$, respectively. There was also a significant interaction between explanations and picture, $F(1,163) = 4.98, p < .027$. Overall, transfer subjects made fewer non-critical errors than control subjects. Further, a Tukey's post hoc test revealed that subjects given functional explanation and the picture made significantly fewer non-critical errors. As observed in Experiment I, most of the non-critical errors occurred in assembling the base of the crane.

The main effects of explanations and picture were not significant for restarts. However, there was a significant effect for transfer, $F(1,163) = 7.64, p < .006$ with the transfer groups showing the least number of restarts. In addition, there was a 2-way interaction (explanations and picture),

$F(1,163) = 4.97, p < .027$ and a 3-way interaction, $F(1,163) = 4.42, p < .037$. Tukey's post hoc tests found that no two groups were significantly different at the .05 level.

In summary, for the initial assembly measures, experience in building the lighthouse facilitated the crane assembly task, however, the predicted facilitative effects for functional explanations did not occur.

Criterion Assembly. A 2 (explanations) by 2 (picture) by 2 (transfer) between groups ANOVA was performed for each of the assembly measures for the criterion assembly. Non-critical errors was the only dependent measure that showed no significant differences among groups. Table 9 presents the means and standard deviations for the criterion assembly measures.

Table 9
Experiment II:
Means for Criterion Assembly Measures

Control Group	Structural N-P <i>n</i> = 20		Structural PIC <i>n</i> = 24		Functional N-P <i>n</i> = 22		Functional PIC <i>n</i> = 23	
	<i>Mean</i>	<i>S.D.</i>	<i>Mean</i>	<i>S.D.</i>	<i>Mean</i>	<i>S.D.</i>	<i>Mean</i>	<i>S.D.</i>
Total errors	06.20	07.60	08.45	18.88	02.95	02.29	03.17	04.25
Critical errors	04.90	07.60	07.50	16.36	02.00	02.18	02.43	03.55
Non-critical errors	01.30	01.08	00.95	02.89	00.95	00.89	00.73	01.25
Restarts	00.15	00.36	00.41	01.13	00.00	00.00	00.17	00.65
Transfer Groups	Structural N-P <i>n</i> = 20		Structural PIC <i>n</i> = 22		Functional N-P <i>n</i> = 21		Functional PIC <i>n</i> = 19	
	<i>Mean</i>	<i>S.D.</i>	<i>Mean</i>	<i>S.D.</i>	<i>Mean</i>	<i>S.D.</i>	<i>Mean</i>	<i>S.D.</i>
Total errors	02.35	03.21	01.95	01.98	02.28	03.24	03.15	03.90
Critical errors	01.65	03.10	01.50	01.94	01.42	02.95	02.73	03.73
Non-critical errors	00.70	00.97	00.45	00.73	00.85	00.96	00.42	00.90
Restarts	00.00	00.00	00.04	00.21	00.00	00.00	00.00	00.00

Note. N-P = No-Picture, PIC = Picture.

For total criterion errors, there was a significant main effect for transfer and a significant 2-way interaction between the explanations and transfer, $F(1,163) = 5.24, p < .023$, and $F(1,163) = 3.90, p < .05$, respectively. Subjects made fewer total errors (critical and non-critical) in the transfer groups than in the control groups. Further, simple effects analyses showed that subjects in the transfer structural group made significantly fewer errors than subjects in the control structural group, $F(1,167) = 9.43, p < .002$.

For critical criterion errors, there was a significant effect for transfer and a 2-way interaction between the explanations and transfer variables, $F(1,163) = 4.99, p < .027$ and $F(1,163) = 4.28, p < .04$, respectively. Subjects made fewer critical errors in the transfer than in the control group. Simple effects analyses revealed that subjects in the transfer structural group made significantly fewer errors than subjects in the control structural group, $F(1,167) = 9.61, p .002$, while there were no differences among subjects in the functional control, functional transfer, and structural transfer groups.

The criterion assembly showed very few restarts by either the control or transfer groups. In fact, in the no-picture condition, transfer subjects made no restarts. There was a significant main effect for transfer, $F(1,163) = 5.12, p < .02$, with the transfer subjects making the fewest number of restarts. There was no significant interaction.

In summary, the results for the criterion assembly measures are similar to those for the initial assembly. Transfer occurred but there were no facilitative effects for functional explanations. The 2-way interactions for critical and total errors may be the result of structural explanation transfer subjects forming sufficient mental models during the lighthouse assembly to significantly reduce errors during the subsequent crane assembly.

Component Names Tests

A 2 (explanations) by 2 (pictures) by 2 (transfer) by 2 (test types) MANOVA was conducted on the two written tests (fill-in-the-blank and matching) that were administered after subjects completed their criterion assemblies. Table 10 presents the means and standard deviations for this analysis.

Table 10
Experiment II:
Means for Component Names Tests

Control Group	Structural N-P <i>n</i> = 20		Structural PIC <i>n</i> = 24		Functional N-P <i>n</i> = 22		Functional PIC <i>n</i> = 23	
	<i>Mean</i>	<i>S.D.</i>	<i>Mean</i>	<i>S.D.</i>	<i>Mean</i>	<i>S.D.</i>	<i>Mean</i>	<i>S.D.</i>
Fill-in Test	14.00	04.10	11.29	04.04	12.72	04.68	11.82	03.71
Match Test	18.10	01.16	17.25	02.32	17.90	01.30	17.82	01.46
Transfer Groups	Structural N-P <i>n</i> = 20		Structural PIC <i>n</i> = 22		Functional N-P <i>n</i> = 21		Functional PIC <i>n</i> = 19	
	<i>Mean</i>	<i>S.D.</i>	<i>Mean</i>	<i>S.D.</i>	<i>Mean</i>	<i>S.D.</i>	<i>Mean</i>	<i>S.D.</i>
Fill-in Test	15.10	01.88	13.63	03.69	15.66	02.17	13.68	02.96
Match Test	18.80	00.52	17.95	01.52	18.38	01.02	17.73	01.62

Note. N-P = No-Picture, PIC = Picture (Possible Score = 19).

There were significant main effects for pictures and transfer, $F(1,163) = 14.08, p < .000$ and $F(1,163) = 16.28, p < .000$, respectively. Subjects in the no-picture and transfer groups had higher scores. There was also a significant effect for types of test, $F(1,163) = 267.35, p < .000$, with subjects scoring higher on the matching tests than on the fill-in-the-blank tests.

There were significant 2-way interactions for the picture and the test type and for transfer and test type, $F(1,163) = 4.43, p < .037$ and $F(1,163) = 8.75, p < .004$, respectively. Simple effects analyses revealed significant differences between the control and transfer groups for the fill-in-the-blank test and approached significance for the matching test, $F(1,163) = 14.22, p < .000$ and $F(1,163) = 3.88, p < .050$, respectively. Subjects in transfer groups scored higher on the fill-in-the-blank test. Simple effects also showed significant differences between the picture groups for both

the fill-in-the-blank and matching tests, $F(1,163) = 10.42, p < .002$ and $F(1,163) = 7.13, p < .008$, respectively. Subjects in the no-picture groups scored higher on both tests.

The results from the fill-in-the-blank and matching tests show significant transfer effects for both tests. Also, as in Experiment I, subjects in the no-picture groups remembered more component names than subjects in the picture groups.

Conclusions

The results of Experiment I indicate that for an assembly task (1) the picture facilitated learning by decreasing the time required to complete the initial assembly but did not affect the criterion or retention assembly times, (2) functional qualitative explanations combined with the picture reduced the number of restarts and non-critical errors during learning, (3) when given the opportunity, subjects preferred to study the picture and instructions together during learning, (4) functional explanations reduced the critical and total errors made during the criterion and retention assemblies, (5) there was a significant decline in assembly accuracy and time measures over the 1 week retention interval, (6) performance on the component name test improved over the retention interval for fill-in-the-blank questions, and (7) subjects in the no-picture groups performed better than subjects in the picture groups on both the fill-in-the-blank and matching portions of the test.

The predicted results for time measures may be attributed to hands-on experience with the device during initial learning, which apparently minimized differences between the picture and no-picture groups on the criterion and retention trials. The better performance during initial learning for the functional explanations plus picture subjects on restarts and non-critical errors indicates that they were developing a better model of the assembly task as they were learning. As predicted, for the subjects in the functional explanation groups, this superior model facilitated both criterion and retention assembly performance by reducing total and critical errors. In conclusion, providing pictures can decrease learning time for a procedural task while providing functional explanations can improve performance accuracy.

The results of Experiment II show that learning an assembly task does transfer to learning a new but similar task in the same domain. Subjects in the transfer conditions performed better on almost all dependent measures. Further, as predicted, having a picture decreased the time required to complete the initial assembly in both the control and transfer conditions, but did not affect the criterion assembly time. However, unlike Experiment I, the effects of functional compared to structural explanations were minimal for the transfer subjects. For the initial assembly there were no main effects for explanations and the predicted interactions did not occur. The interactions that were observed were not strong enough to result in significant differences in post hoc comparisons. It may be that subjects in the structural explanations groups in the transfer condition formed effective mental models while learning the first task, which may have minimized differential effects. The interaction between explanations and transfer for total and critical errors during the criterion assembly supports this hypothesis. This interaction resulted from the better performance for the functional versus the structural explanation groups in the control condition compared to no difference between explanation groups in the transfer condition. Apparently, in the transfer condition, subjects in the structural groups have had enough experience with the assembly materials so that their errors are reduced to the level of the functional subjects.

In contrast, the interaction among study activities, explanations, and transfer for the picture groups provides evidence that functional explanations did have an effect that carried over to learning the transfer task. In the control condition both the functional explanation-picture subjects and the structural explanation-picture subjects spent between two-thirds and three-quarters of their study time looking at the instructions or the instructions and picture together and the remainder of the time looking at the picture by itself. In the transfer condition, these proportions remained the same for the structural explanation-picture subjects while the functional explanation-picture spent less than half their time looking at the instructions or the instructions and picture together. Exposure to the functional instructions, while learning the first task for transfer subjects, provided them with enough knowledge so that they spent significantly less time with the instructions while learning the transfer task.

In both experiments, performance on the component names tests was higher for subjects in the no-picture conditions. This probably occurred because no-picture subjects spent significantly more time studying the instructions, which referred to the part names, than picture subjects. As expected, recognition tests scores were higher than recall test scores and the transfer subjects performed better than the control subjects.

In conclusion, functional instructions can be effective in learning to perform a procedural task, however, their effects are diminished when learning subsequent similar tasks. Providing pictures also facilitates learning but does not help performance once the task has been learned to criterion. Having pictures during learning, however, resulted in poorer learning and memory for the names of the assembly kit components. Finally, consistent with previous research (e.g., Mayer, 1989; Swezey et al., 1991), previous experience in a task domain does result in positive transfer to new tasks.

Recommendations

The Chief of Naval Education and Training and its subordinate commands should promote the use of functional explanations in training courses and manuals to improve performance and increase retention of procedural tasks. Navy instructional designers and developers should incorporate elaborated explanations of cause and effect relationships in technical training and text to enhance students' mental models and increase retention in the use of procedural tasks. In addition, pictures should continue to be used in combination with lecture and text as appropriate. Finally, when possible, trainees should be given experience with more than one type or model of the equipment they will encounter on the job. This will facilitate transfer when they are required to work with systems and devices that are similar but not identical to the ones used during training.

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